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U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

ATTORNEY'S DOCKET NUMBER

**TRANSMITTAL LETTER TO THE UNITED STATES  
DESIGNATED/ELECTED OFFICE (DO/EO/US)  
CONCERNING A FILING UNDER 35 U.S.C. 371**

A-417

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR

**10/018606**

INTERNATIONAL APPLICATION NO.  
**PCT/JP00/04493**

INTERNATIONAL FILING DATE  
**6 July 2000**

PRIORITY DATE CLAIMED  
**7 July 1999**

TITLE OF INVENTION

**INDUCTOR ELEMENT**

APPLICANT(S) FOR DO/EO/US

**Akira OKAMOTO et al**

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (24) indicated below.
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
  - a. ☐ is attached hereto (required only if not communicated by the International Bureau).
  - b. ☒ has been communicated by the International Bureau.
  - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
  - a. ☒ is attached hereto.
  - b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
  - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
  - b. ☐ have been communicated by the International Bureau.
  - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
  - d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).
11. ☒ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☒ A copy of the International Search Report (PCT/ISA/210).

**Items 13 to 20 below concern document(s) or information included:**

13. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☐ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☐ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
20. ☒ A second copy of the published international application under 35 U.S.C. 154(d)(4).
21. ☒ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
22. ☒ Certificate of Mailing by Express Mail
23. ☒ Other items or information:

Inventor Information Sheet (Patent Bibliographical Data)

Copy of Form PCT/IB/308

English translation of International Search Report

PTO-1449 and copy of document listed thereon with 2nd copy of English trans. of International Search Report

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U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR 1.101) <b>10/013606</b>		INTERNATIONAL APPLICATION NO. <b>PCT/JP00/04493</b>		ATTORNEY'S DOCKET NUMBER <b>A-417</b>	
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24. The following fees are submitted: <b>BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :</b>				<b>CALCULATIONS PTO USE ONLY</b>	
<input type="checkbox"/> Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO ..... <b>\$1040.00</b>					
<input checked="" type="checkbox"/> International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO ..... <b>\$890.00</b>					
<input type="checkbox"/> International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO ..... <b>\$740.00</b>					
<input type="checkbox"/> International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) ..... <b>\$710.00</b>					
<input type="checkbox"/> International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) ..... <b>\$100.00</b>					
<b>ENTER APPROPRIATE BASIC FEE AMOUNT =</b>				<b>\$890.00</b>	
Surcharge of <b>\$130.00</b> for furnishing the oath or declaration later than _____ months from the earliest claimed priority date (37 CFR 1.492 (e)). <input type="checkbox"/> 20 <input type="checkbox"/> 30				<b>\$0.00</b>	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	24 - 20 =	4	x \$18.00	<b>\$72.00</b>	
Independent claims	2 - 3 =	0	x \$84.00	<b>\$0.00</b>	
Multiple Dependent Claims (check if applicable).				<input type="checkbox"/> <b>\$0.00</b>	
<b>TOTAL OF ABOVE CALCULATIONS =</b>				<b>\$962.00</b>	
<input type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.				<b>\$0.00</b>	
<b>SUBTOTAL =</b>				<b>\$962.00</b>	
Processing fee of <b>\$130.00</b> for furnishing the English translation later than _____ months from the earliest claimed priority date (37 CFR 1.492 (f)). <input type="checkbox"/> 20 <input type="checkbox"/> 30 +				<b>\$0.00</b>	
<b>TOTAL NATIONAL FEE =</b>				<b>\$962.00</b>	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) (check if applicable).				<input checked="" type="checkbox"/> <b>\$40.00</b>	
<b>TOTAL FEES ENCLOSED =</b>				<b>\$1,002.00</b>	
				Amount to be: refunded \$ charged \$	

a. ☒ A check in the amount of \$1,002.00 to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. \_\_\_\_\_ in the amount of \_\_\_\_\_ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☐ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. \_\_\_\_\_. A duplicate copy of this sheet is enclosed.

d. ☒ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

**NOTE:** Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

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## DESCRIPTION

## INDUCTOR ELEMENT

## Technical Field

The present invention relates to an inductor element that is formed on various kinds of substrates such as a semiconductor substrate.

## Background Art

There is known such a semiconductor circuit that forms a spiral pattern electrode on a semiconductor substrate with using thin film forming technique and uses this pattern electrode as an inductor element. If current flows in such an inductor element that is formed on such a semiconductor substrate, magnetic flux is generated in the direction perpendicular to the spiral pattern electrode. Nevertheless, since eddy currents are induced on the front side of the semiconductor substrate by this magnetic flux to cancel effective magnetic flux, there is a problem of not effectively functioning as the inductor element. In particular, the higher a frequency of a signal that flows in the inductor element becomes, the more remarkable this inclination becomes, and hence it is difficult to form a high-frequency circuit, containing an inductor element, on a semiconductor substrate.

## Disclosure of the Invention

The present invention has been developed to solve the above mentioned problems, and its object is to provide an inductor

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An inductor element of the present invention has two conductors that are formed in piles on a substrate in the state where they are mutually insulated, and are connected with each other at both odd ends. While one conductor separating from the substrate is used as an inductor conductor, a lead wire of this inductor conductor is led out through a gap between another conductor, being near the substrate, and the substrate. When two conductors that are mutually connected at both odd ends are located in piles on a substrate and one of the conductors apart from the substrate is used as an inductor conductor, it has been verified in experiments that predetermined inductance is kept without an inductance component disappearing by eddy currents etc. even if this inductor conductor is formed on the substrate. In particular, by leading out the lead wire of this inductor conductor from between another conductor and the substrate, it becomes possible to preventing the flow of the effective magnetic flux, generated by the inductor conductor, to the minimum from being interrupted. Hence good characteristics can be obtained.

In particular, it is desirable to form three or more layers of metal layers on the substrate described above, and to form the two conductors described above and lead wires respectively with using different metal layers which are mutually apart by one or more layers. Since the inductor conductor can be made to be apart from the lead wires by at least two or more layers by adopting such constitution, it is possible to further reduce the influence of the electric current that flows in the lead wires.

In addition, it is desirable to connect the two conductors at both odd ends with using a part of a lead wire of the inductor conductor extending from the one end of the inductor conductor. Since the number of the conducting wires (lead wires and connecting wires) that intersect the inductor conductor can be reduced, a degree of interrupting the flow of the effective magnetic flux generated by the inductor conductor can be further reduced. In addition, since the shape of a mask can be simplified when manufacturing each conductor and lead wires with using an aligner etc., it is possible to reduce a manufacturing cost and manufacturing labor hours.

Furthermore, an inductor element of the present invention has two conductors that are formed in piles on a substrate in the state where they are mutually insulated, and are connected with each other at both odd ends. While using one conductor apart from the substrate as an inductor conductor, one end of another conductor not connected to the inductor conductor is terminated with a predetermined impedance element. Although electric current flows also in another conductor by the effective magnetic flux generated by the inductor conductor, it becomes possible to prevent unnecessary reflection in this portion and to improve characteristics by terminating the end of the free side of another conductor with the impedance element. In addition, it is possible to adjust frequency characteristics or the like of another conductor by forming the impedance element with using any of a resistor, a capacitor, and an inductor or combining these. Hence it becomes possible also to improve characteristics by adjusting a device constant of the impedance element at a suitable value.

In addition, it is desirable to adjust termination conditions by making it possible to change at least one device constant of a resistor, a capacitor, and an inductor, which constitute the impedance element described above, and making this device constant variable. By some external means, for example, by changing a value of a control voltage applied, it becomes possible to adjust a device constant of the whole impedance element, that is, characteristics of the inductor element by a change of termination conditions.

In particular, when the substrate described above is a semiconductor substrate, it is desirable to form the capacitor where a device constant can be changed by a variable capacitance diode. While it becomes possible to miniaturize parts by using the variable capacitance diode formed with using the semiconductor substrate, it becomes possible to reduce a manufacturing cost by simplifying manufacturing process in comparison with the case where external parts are attached thereafter, and wiring etc. are performed. Similarly, when the substrate described above is a semiconductor substrate, it is desirable to form a variable resistor made of an FET whose channel is used as a resistor. While it is possible to miniaturize parts by using the variable resistor made of the FET formed with using the semiconductor substrate, it becomes possible to reduce a manufacturing cost by simplifying manufacturing process in comparison with the case where external parts are attached thereafter, and wiring etc. are performed.

In addition, it is desirable to form an inductor, which constitutes the impedance element, by a conductive layer formed on the substrate in predetermined shape. Since high Q is not

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required of the inductor used for terminating one end of a conductor, it is possible to realize the inductor with a conductor pattern on the substrate. Moreover, since it becomes possible to form this conductor pattern at the same process with using a metal layer for performing various kinds of wiring etc., it becomes possible to perform miniaturization of parts, simplification of process, and cost reduction.

In addition, it is desirable to form two conductors, described above, in the approximately same shape or long shape. Since an upper conductor never directly faces the front side of the substrate owing to making the two conductors the same in shapes, it is possible to reduce the eddy currents that are generated on the substrate when the upper conductor directly faces the substrate. In addition, it is possible to give predetermined inductance to the upper conductor by making the shapes of the two conductors be long. In particular, since it is possible to give large inductance to a conductor when the conductor is formed in one or more turns of spiral shape or a meander shape, the conductor is suitable for being built in a comparatively low frequency circuit. In addition, since it is possible to give a small inductance to a conductor when the conductor is formed in a circular shape less than one turn or an substantially linear shape in comparison with the case where the conductor is formed in a spiral shape or the like, the conductor is suitable for being built in a comparatively high frequency circuit.

Moreover, when two conductors are made in spiral shapes, it is preferable to connect an inner end of one conductor with an outer end of another conductor. Since it is experimentally

confirmed that it is possible to secure further large inductance when an inductor conductor is formed on a substrate owing to performing such connection, it is possible to realize the inductor element that effectively functions on a substrate. In particular, when the shape is a spiral one having one or more turns, it is necessary to extend a lead wire from the inner circumferential end of the inductor conductor having this spiral shape. Nevertheless, it is possible to suppress to the minimum the interruption of flow of the effective magnetic flux, generated by the inductor conductor, by leading out the lead wire between the conductor, being near the substrate, and the substrate.

In addition, the inductor element described above is suitable for use as a compound element that also has a capacitance component besides an inductance component. Since this inductor element has two conductors that are superimposed one on the other and its characteristics also include a capacitance component, this inductor element can be used in applications where an inductor and a capacitor are combined for making them a part of a circuit.

#### Brief Description of the Drawings

FIG. 1 is a schematic diagram showing a planar structure of an inductor element according to a first embodiment;

FIG. 2 is a drawing showing an upper layer of conductor included in the inductor element shown in FIG. 1;

FIG. 3 is a drawing showing a shape of a lower layer of conductor included in the inductor element shown in FIG. 1;



FIG. 4 is a drawing showing a connection state of two conductors included in an inductor conductor;

FIG. 5 is an enlarged sectional view taken on line V-V in FIG. 1;

FIG. 6 is a graph showing experimental result;

FIG. 7 is a graph showing experimental result;

FIG. 8 is a graph showing experimental result;

FIG. 9 is a graph showing experimental result;

FIG. 10 is a circuit diagram of an oscillation circuit including an inductor element;

FIG. 11 is a chart showing an output characteristic of the oscillation circuit shown in FIG. 10;

FIG. 12 is a chart showing an output characteristic of the oscillation circuit shown in FIG. 10;

FIG. 13 is a schematic diagram showing a structure of an inductor element according to a second embodiment;

FIG. 14 is a drawing showing the structure in the case of connecting a variable capacitance diode to the inner circumferential end of a lower layer of conductor;

FIG. 15 is a drawing showing the cross-sectional structure in the case of forming the variable capacitance diode, shown in FIG. 14, on a semiconductor substrate;

FIG. 16 is a diagram showing the structure in the case of connecting a variable resistor to the inner circumferential end of a lower layer of conductor;

FIG. 17 is a schematic diagram showing a modified example of the conductor included in the inductor element;

FIG. 18 is a schematic diagram showing a modified example of the conductor included in the inductor element;

FIG. 19 is a schematic diagram showing a modified example of the conductor included in the inductor element; and

FIG. 20 is a drawing showing a modified example of the inductor element, the drawing where a connecting wire that connects ends of two conductors is omitted.

#### Best Mode for Carrying Out the Invention

Hereafter, an inductor element according to an embodiment where the present invention is applied will be specifically described with referring to drawings.

##### [First Embodiment]

FIG. 1 is a schematic diagram showing a planar structure of an inductor element according to the first embodiment. In addition, FIG. 2 is a drawing showing an upper layer of conductor included in the inductor element shown in FIG. 1. FIG. 3 is a drawing showing a shape of a lower layer of conductor included in the inductor element shown in FIG. 1.

An inductor element 100 according to this embodiment has two conductors 120 and 122 that have spiral shapes and are formed in the front side of a semiconductor substrate 110. These two conductors 120 and 122 have substantially the same shape. When viewed from the front side of the semiconductor substrate 110, they are formed so that the conductor 120, which becomes an upper layer, and another conductor 122, which becomes a lower layer, are formed by being superimposed one on the other substantially exactly. Each of the conductors 120 and 122 is formed of, for examples, a thin film of metal (metal layer), or semiconductor material such as poly silicon.

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FIG. 4 is a schematic diagram showing a connection state of the two conductors 120 and 122, described above. As shown in FIG. 4, lead wires 130 and 132 are connected to an outer end (outer circumferential end) and an inner end (inner circumferential end) of the upper conductor 120 respectively, and the inner end of the upper conductor 120 and the outer end of the lower conductor 122 are connected with a connecting wire 134.

The upper conductor 120 functions as an inductor conductor, and is connected to a circuit (not shown) formed on the semiconductor substrate 110 through the lead wires 130 and 132 connected to ends thereof.

FIG. 5 is an enlarged sectional view taken on line V-V in FIG. 1. As shown in FIGS. 4 and 5, at least three layers of metal layers 160, 162, and 164 are formed on the surface of the semiconductor substrate 110. One conductor 120 as an inductor conductor is formed with using a top layer of metal layer 160 that is most apart from the semiconductor substrate 110, and another conductor 122 is formed with using a middle layer of metal layer 162.

In addition, the lead wire 132 led out from the inner circumferential end of the top layer of conductor 120 is formed with using a bottom layer of metal layer 164 nearest to the semiconductor substrate 110. For example, as shown in FIG. 5, the inner circumferential end of the conductor 120 and one end of the lead wire 132 are connected through a through hole 150. The lead wire 132 formed from the bottom layer of metal layer 164 is led out outward so that the lead wire 132 may be orthogonal to each circumferential portion of the inductor conductor with

a spiral shape. In addition, insulating layers 140, 142, and 144 are formed between the conductors 120 and 122, and the lead wire 132, which are formed with using three metal layers 160, 162, and 164, and the semiconductor substrate 110 respectively, and mutual insulation is performed.

An inductor element 100 in this embodiment has the structure described above. Since predetermined inductance appears between the lead wires 130 and 132 connected to both ends of the upper layer of conductor 120 respectively, this upper conductor 120 can be used as an inductor conductor. In addition, under this upper conductor 120, the conductor 122 that has substantially the same shape as this conductor 120 is formed. It is possible to suppress the generation of eddy currents in the front side of the semiconductor substrate 110 when an upper conductor 120 is used as an inductor conductor, by connecting one end of the upper conductor 120 with one end of the lower conductor 122 with the connecting wire 134. Hence it is possible to make the upper conductor 120 effectively function as an inductor conductor.

Furthermore, in the inductor element 100 in this embodiment, the lead wire 132 led out from the inner circumferential end of the upper layer of conductor 120 serving as an inductor conductor is formed with using the bottom layer of metal layer 164, and is located with being most apart from the inductor conductor through the other conductor 122. Hence it is possible to suppress to the minimum interruption of flow of the effective magnetic flux generated by the inductor conductor, and to obtain good characteristics. In this manner, the inductor element 100 in this embodiment can be formed with using at least three layers

of metal layers 160, 162, and 164 on the surface of the semiconductor substrate 110. Hence it becomes possible to realize forming the inductor element 100 with other parts in one piece to perform integration on the semiconductor substrate 110.

By the way, the present applicant performed various kinds of experiments about the effectiveness of an inductor element formed by locating the two conductors 120 and 122, described above, in piles on a substrate and mutually connecting both odd ends. Then, the present applicant has already applied for a patent on the basis of the experimental result (Japanese Patent Application No. H10-93869). The inductor element 100 in this embodiment is an advanced one, and is intended to improve characteristics by devising a leading-out position of the lead wire 132 with using that the two conductors 120 and 122 have two layer structure. For example, supposing that an inductor conductor with a spiral shape is simply formed on a semiconductor substrate or another substrate, even if a lead wire is formed with using an upper layer or a lower layer of metal layer which is adjacent to a metal layer in which this inductor conductor is formed, it is the same that the inductor layer and the lead wire are closely located. Hence the lead wire interrupts the effective magnetic flux generated by the inductor conductor. However, in the inductor element 100 in this embodiment, another conductor 122 is located between one conductor 120, serving as an inductor conductor, and the lead wire 132. Hence it is possible to reduce the turbulence of the effective magnetic flux at the time of leading out the lead wire 132 so that the lead wire 132 may intersect the inductor conductor 120.

Hereafter, the effectiveness of the inductor element in this embodiment will be described with reference to the experimental result shown in the application described above (Japanese Patent Application No. H10-93869).

FIG. 6 is a graph showing the measurement result of the forward gain of an inductor element which has an electrode of one layer having the same shape as the conductor 120 included in the inductor element 100. In addition, FIG. 7 shows a characteristic, which is the forward gain of an inductor element which has an electrode of one layer having the same shape as the conductor 120 included in the inductor element 100, at the time of closely contacting a conductor substrate to this inductor element.

As for the inductor element used in this measurement, a five-turn electrode having one-mm pattern width and a 0.2-mm adjacent gap of spiral pattern was formed on a front side of a 0.13-mm-thick insulating member with a dielectric constant of 3.17. The characteristic shown in FIG. 6 was measured with sufficiently separating this inductor element from other conductive members. The characteristic shown in FIG. 7 was measured with closely contacting a copper plate to a front side of the insulating member in an opposite electrode side of this inductor element. In addition, vertical axes in FIGS. 6 and 7 (this is the same also in FIGS. 8 and 9 which are described later) denote forward gain (attenuations) logarithmically expressed, and horizontal axes denote the frequencies of input signals logarithmically expressed, respectively.

In an inductor element which consists of one layer of electrode with a spiral shape, in a state that the inductor element

is sufficiently separated from other conductive members, as shown in FIG. 6, as the frequency of an input signal becomes high, the forward gain becomes smaller. This is because the fact that the impedance of the inductor element having the predetermined inductance  $L$  is  $j\omega L$  and becomes large in proportion to the frequency of the input signal.

On the other hand, as shown in FIG. 7, in the state that this inductor element is closely contacted to the copper plate, it is possible to maintain a high forward gain even if the input signal changes. This shows that this inductor element does not function as an original inductor since the inductance that this inductor element has becomes small by bringing the copper plate close to this inductor element. An estimated cause of decreasing the inductance is that eddy currents arise on the front side of the copper plate owing to magnetic flux, which is generated when a signal is inputted into the electrode, and cancel this magnetic flux.

In addition, in the measurement described above, although the copper plate was used as a substrate, even in the case that a semiconductor substrate is used instead of the copper plate, the same phenomenon happens fundamentally.

FIG. 8 is a graph showing the measurement result of the forward gain of an inductor element having two layers of electrodes that have the same shape and arrangement as the two conductors 120 and 122 included in the inductor element 100. In addition, FIG. 9 shows the forward gain of an inductor element having two layers of electrodes that have the same shape and arrangement as the two conductors 120 and 122 included in the

inductor element 100, at the time of closely contacting a copper plate to this inductor element.

The inductor element used for these measurements has the structure that an electrode corresponding to the conductor 122 shown in FIG. 1 is added to the inductor element shown in the measurement result in FIGS. 6 and 7. In addition, if closely contacting the copper plate to this inductor element, the lower electrode and copper plate are arranged through an adequate thin insulating member.

A resonance point appears at nearly 117 MHz as it is apparent from the forward gain characteristic shown in FIG. 8 in a state that the inductor element where two layers of electrodes which have spiral shapes is sufficiently separated from other conductive members. This is because this inductor element functions as a whole as a compound element that has an inductance component and a capacitance component since capacitance is produced between two electrodes while one electrode functions as an inductor conductor.

In addition, in a state of closely contacting this inductor element to the copper plate, as shown in FIG. 9, a similar resonance point appears although the position of a resonance point (135 MHz) shifts. This shows that, by using the inductor element that has the double structure of the electrodes described above, even if the inductor element is closely contacting to the copper plate, the inductance component does not disappear and the function as an inductor conductor is maintained.

In addition, since the capacitance between two electrodes surely accompanies the inductor element that has double-structure electrodes, it is preferable to use it as one



part of a circuit, where its resonance characteristic is used, as an application. For example, it is preferable to use it as an inductor element 100 in an oscillation circuit, a tuning circuit, or the like.

Next, a specific example at the time of using the inductor element 100 according to this embodiment described above as one part of an actual circuit will be described.

FIG. 10 shows the structure of a Clapp oscillator that is an example of an oscillation circuit constituted by using the inductor element 100 according to this embodiment. In this Clapp oscillator, the capacitance of two capacitors 20 and 22 may be several tens times the between-terminal capacity of a transistor 24. In addition, an inductor element 30 is connected through a capacitor 28.

FIG. 11 is a chart showing the output characteristic of an oscillation circuit where the inductor element, which has one layer of electrode and the result of the measurements of whose forward gain is shown in FIG. 6, is used as the inductor element 30 in the Clapp oscillator shown in FIG. 10. As shown in FIG. 11, an oscillation frequency of 119 MHz was observed.

In addition, FIG. 12 is a chart showing the output characteristic of an oscillation circuit where the inductor element, whose two-layer electrodes are closely contacted to the copper plate and the result of the measurements of whose forward gain is shown in FIG. 9, is used as the inductor element 30 in the Clapp oscillator shown in FIG. 10. As shown in FIG. 12, an oscillation frequency of 127 MHz is observed.

Thus, it can be seen that the inductor element having the two-layer electrodes functions as an inductor conductor without

losing an inductance component even if it is closely contacted to the copper plate in its one side (the side opposite to the electrode used as the inductor conductor). Hence, the inductor element 100 according to this embodiment which has the fundamentally same structure can effectively function as an inductor element which has predetermined inductance even if it is formed so that it may be closely contacted to the front side of the semiconductor substrate 110 by providing the lower conductor 122 besides the upper conductor 120.

[Second Embodiment]

FIG. 13 is a diagram showing the structure of an inductor element 100A in a second embodiment. This is different in that a predetermined impedance element 200 is added to the inductor element 100 in the first embodiment shown in FIG. 4.

Namely, in the inductor element 100 in the first embodiment described above, with paying attention to the other conductor 122 located so as to substantially superimpose the one conductor 120 serving as an inductor conductor, only one end (the outer circumferential end in the example shown in FIG. 1) is connected to the connecting wire 134 and the inner circumferential end is free (open state). In this embodiment, the characteristics of the whole inductor element 100A can be improved or adjusted by terminating the inner circumferential end of the conductor 122 with the impedance element 200.

For example, when electric current flows into the one conductor 120 of the inductor element 100A, induced current flows to or electric current directly flows through the connecting wire 134 into the other conductor 122. However, it becomes possible to prevent unnecessary reflection in this inner

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circumferential end by terminating the inner circumferential end of the other conductor 122 through the impedance element 200. In addition, it becomes easy to improve or change the frequency characteristic of a circuit including the inductor element 100A by adjusting or changing a device constant of the impedance element 200. For example, what is necessary to make a frequency low is just to use an inductor as the impedance element 200. On the contrary, what is necessary to make a frequency high is just to use a capacitor as the impedance element 200. Alternatively, the impedance element 200 can be formed with arbitrarily combining these, that is, an inductor, a capacitor, and a resistor.

In addition, a chip part of an inductor, a capacitor, or a resistor can be most easily used for the impedance element 200 described above. In addition, in consideration of forming two conductors 120 and 122, and the like, which constitute the inductor element 100A, on the semiconductor substrate 110 as shown by the cross-sectional structure in FIG. 5, it is desirable also to form the impedance element 200 on the semiconductor substrate 110 with using semiconductor manufacturing technology. For example, what is conceivable is to form a resistor with using a highly resistive material, to form a capacitor with making two layers of metal layers, having predetermined areas, face each other, or to form an inductor with using conductors having predetermined shapes. In addition, since the impedance element 200 is used as an element for termination, not-so-high Q is required even if this is realized with an inductor. For this reason, it also becomes possible to use an inductor constituted by forming a conductor with a predetermined shape (for example,

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a spiral shape) on the semiconductor substrate 110 as the impedance element 200.

In addition, it is also good to use the impedance element 200 whose device constant can be changed by external control means. FIG. 14 is a diagram showing the structure in the case of connecting a variable capacitance diode 210 to the inner circumferential end of the conductor 122. The variable capacitance diode 210 operates as a capacitor with predetermined capacitance by using it in a reverse biased state, whose capacitance is changed by changing a reverse bias voltage. This variable capacitance diode 210 is connected to the inner circumferential end of the conductor 122 through a capacitor 212 for DC component removal.

FIG. 15 is a drawing showing the cross-sectional structure in the case of forming the variable capacitance diode 210, shown in FIG. 14, on the semiconductor substrate 110. As shown in FIG. 15, a p<sup>+</sup> region 220 formed near the surface of the semiconductor substrate 110 formed of an n type silicon substrate (n-Si substrate) and an n<sup>+</sup> region 222 further formed in a part thereof are included, and these p<sup>+</sup> regions 220 and n<sup>+</sup> region 222 form a pn junction layer. In addition, an electrode 230 for grounding is formed on the surface of the p<sup>+</sup> region 220, and an electrode 232 for applying an variable reverse bias voltage as a control voltage V<sub>c</sub> is formed on the surface of the n<sup>+</sup> region 222. By applying the positive control voltage V<sub>c</sub> to the electrode 232, the variable capacitance diode 210 whose capacitance changes according to the amplitude of this control voltage V<sub>c</sub> can be formed.

FIG. 16 is a diagram showing the structure in the case of connecting a variable resistor, formed of an FET 240, to the inner circumferential end of the conductor 122. As shown in FIG. 16, the variable resistance is easily realizable by using a channel of the FET 240 as a resistor. By changing the control voltage  $V_c$  applied to a gate electrode, the resistance of the channel formed between a source and a drain can be changed. In addition, the FET 240 can be easily formed on the semiconductor substrate 110 by forming a source region and a drain region near the surface of the semiconductor substrate 110, and forming electrodes with predetermined shapes near regions in which the source region and the drain region and channels therebetween are formed.

Thus, it is possible to change termination conditions by terminating one end of the conductor 122 with using an impedance element whose device constant can be changed according to the control voltage  $V_c$  applied from the external. Hence, even if a frequency of a signal inputted into or outputted from the inductor element 100A is changed, it is possible to adjust the termination conditions according to the change, and hence, to improve characteristics.

The present invention is not limited to the above-described embodiments, but various types of modifications are possible within the scope of the gist of the present invention. For example, in the inductor element 100 shown in FIG. 1, the inner end of the upper conductor 120 and the outer end of the lower conductor 122 are connected through the connecting wire 134. Nevertheless, on the contrary, it can be also performed to mutually connect the outer end of the upper conductor 120 and

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the inner end of the lower conductor 122. In addition, it can be also performed to connect either outer ends or both inner ends of conductors 120 and 122 when it is allowed that the inductance of an inductor element becomes small to some extent.

In addition, since two conductors 120 and 122 included in the inductor elements 100 and 100A are formed in spiral shapes in the embodiments described above, it is possible to realize the inductor elements 100 and 100A having large inductance. Nevertheless, it is also good to form two conductors 120 and 122 in meander shapes (FIG. 17). In addition, the inductance of these inductor elements 100 and 100A can be small when it is used as one part of a high frequency circuit. Hence it is also good to form the conductors 120 and 122 less than one turn by reducing the numbers of turns (FIG. 18), or to form it in a substantially linear shape (FIG. 19).

In addition, although the shapes of two conductors 120 and 122 are set substantially similarly in the embodiments described above, it is also good to set them in different shapes. For example, it can be also performed to set the number of turns of the lower conductor 122 to be more than that of the upper conductors 120. Thus, since the upper conductor 120 does not directly face the semiconductor substrate 110 if all or some of the lower conductor 122 is arranged under the upper conductor 120, it is possible to effectively prevent the generation of eddy currents due to the upper conductor 120.

In addition, although the inductor elements 100 and 100A are formed by forming two conductors 120 and 122 on the semiconductor substrate 110 in the embodiments described above, the inductor element in which two conductors 120 and 122 are

formed on a conductor substrate such as a metal is also realizable. From the experimental result shown in FIG. 9, it is confirmed that, even in this case, this effectively functions as the inductor element. If it becomes possible to form the inductor elements 100 and 100A by closely contacting it on a conductor substrate, it also becomes possible to arrange the inductor elements 100 and 100A on a front side of a metal shielding case or the like. Hence it becomes easy to secure an installation space of the inductor element.

In addition, in the inductor elements 100 and 100A in respective embodiments described above, each connecting wire 134 different from the lead wires 130 and 132 is used for mutually connecting both odd ends of the two conductors 120 and 122. Nevertheless, as shown in FIG. 20, it is also good to mutually connect both odd ends of the two conductors 120 and 122 with using a part of one lead wire 132. In this case, the connecting wire 134 becomes unnecessary. Hence it becomes possible to simplify structure, and further, to improve characteristics since it is prevented that unnecessary magnetic flux by the connecting wire 134 is generated, and that effective magnetic flux generated by the inductor conductor is disturbed.

#### Industrial Applicability

As described above, according to the present invention, a conductor that is one of two conductors, both odd ends of which are mutually connected, and is apart from a substrate is used as an inductor conductor, and a lead wire of this inductor conductor passes between another conductor, being near to the substrate, and the substrate. Hence it is possible to suppress

to the minimum the interruption of the flow of effective magnetic flux generated by the inductor conductor, and hence good characteristics can be obtained.

In addition, according to the present invention, electric current flows also to another conductor by effective magnetic flux generated by the inductor conductor. Nevertheless, by terminating the free end of this other conductor by an impedance element, it becomes possible to prevent unnecessary reflection in this portion, and hence, to improve characteristics.

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CLAIMS

1. An inductor element comprising two conductors, characterized in that they are formed in piles on a substrate in the state where they are mutually insulated, and are connected with each other at both odd ends, wherein one conductor apart from the substrate is used as an inductor conductor, and a lead wire of this inductor conductor is led out through a gap between another conductor, being near the substrate, and the substrate.
2. The inductor element according to claim 1, characterized in that three or more layers of metal layers are formed on the substrate, and the two conductors and the lead wires are formed respectively with using the metal layers which are different layers being mutually apart by one or more layers.
3. The inductor element according to claim 1, characterized in that the two conductors are connected at both odd ends with using a part of the lead wire.
4. The inductor element according to claim 1, characterized in that the two conductors have substantially the same shape.
5. The inductor element according to claim 1, characterized in that the two conductors have long shapes, and one end of one conductor in a longitudinal direction is connected with one end of the other in the longitudinal direction.
6. The inductor element according to claim 1, characterized in that the two conductors have circular shapes less than one turn, and one end of one conductor is connected with one end of the other.
7. The inductor element according to claim 1, characterized in that the two conductors have spiral shapes each number of

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turns of which is one or more, and one end of one conductor is connected with one end of the other.

8. The inductor element according to claim 1, characterized in that the two conductors each have a spiral shape having one or more turns, both odd ends are mutually connected, and also, the lead wire led from the inner circumferential end of the inductor conductor is made to pass between the other conductor and the substrate.

9. The inductor element according to claim 1, characterized in that the two conductors are formed in substantially linear shapes, and one end of one conductor is connected with one end of the other.

10. The inductor element according to claim 1, characterized in that the two conductors are formed in meander shapes, and one end of one conductor is connected with one end of the other.

11. The inductor element according to claim 7, characterized in that an inner end of the one conductor is connected with an outer end of the other conductor.

12. The inductor element according to claim 1, characterized by further comprising:

an inductance component of the inductor element; and

a capacitance component between the two conductors.

13. An inductor element comprising two conductors, characterized in that they are formed in piles on a substrate in the state where they are mutually insulated, and are connected with each other at both odd ends, wherein one conductor apart from the substrate is used as an inductor conductor, and further, an end of the other conductor not connected to the inductor conductor is terminated with a predetermined impedance element.

14. The inductor element according to claim 13, characterized in that it is possible to change at least one device constant of a resistor, a capacitor, and an inductor in the impedance element, and termination conditions are changed by making the device constant variable.

15. The inductor element according to claim 14, characterized in that the substrate is a semiconductor substrate, and the capacitor is formed of a variable capacitance diode made of a semiconductor layer formed in the inside or outside of the semiconductor substrate.

16. The inductor element according to claim 14, characterized in that the substrate is a semiconductor substrate, and the resistor is formed of a channel of an FET made of a semiconductor layer formed in the inside or outside of the semiconductor substrate.

17. The inductor element according to claim 13, characterized in that the two conductors have substantially the same shape.

18. The inductor element according to claim 13, characterized in that the two conductors have long shapes, and one end of one conductor in a longitudinal direction is connected with one end of the other in the longitudinal direction.

19. The inductor element according to claim 13, characterized in that the two conductors have circular shapes less than one turn, and one end of one conductor is connected with one end of the other.

20. The inductor element according to claim 13, characterized in that the two conductors have spiral shapes each number of turns of which is one or more, and one end of one conductor is connected with one end of the other.

21. The inductor element according to claim 13, characterized in that the two conductors are formed in substantially linear shapes, and one end of one conductor is connected with one end of the other.

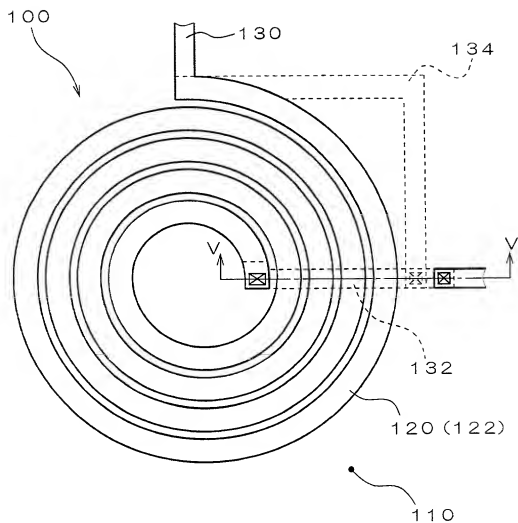
22. The inductor element according to claim 13, characterized in that the two conductors are formed in meander shapes, and one end of one conductor is connected with one end of the other.

23. The inductor element according to claim 20, characterized in that an inner end of the one conductor is connected with an outer end of the other conductor.

24. The inductor element according to claim 13, characterized by further comprising:

- an inductance component of the inductor element; and
- a capacitance component between the two conductors.

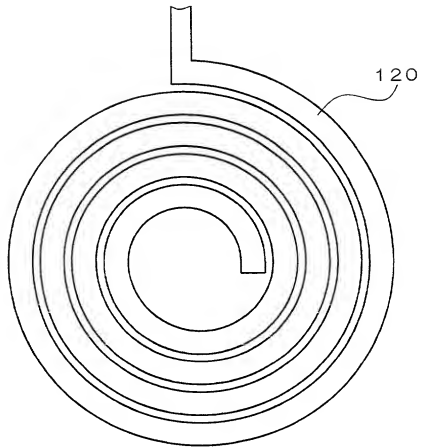
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FIG. 1



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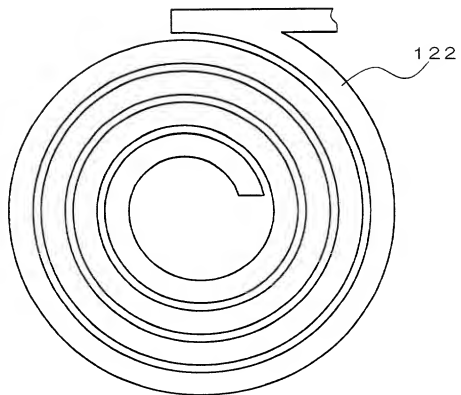
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FIG. 2



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FIG. 3



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FIG. 4

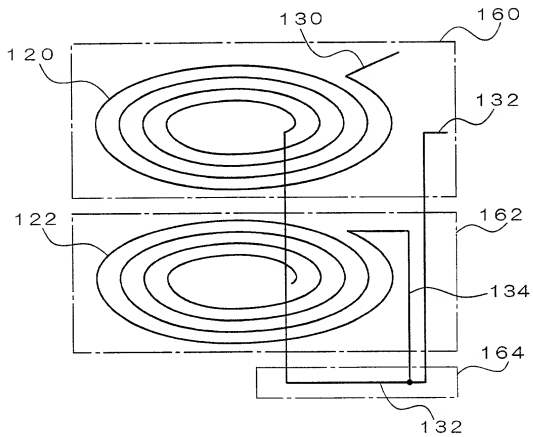
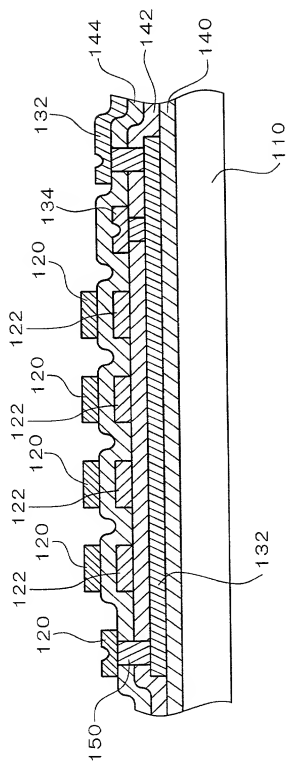




FIG. 5



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FIG. 6

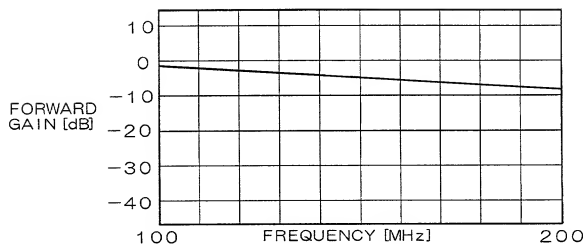
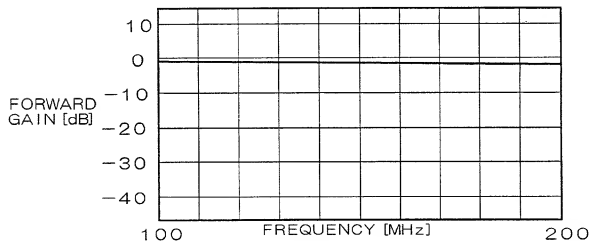


FIG. 7



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FIG. 8

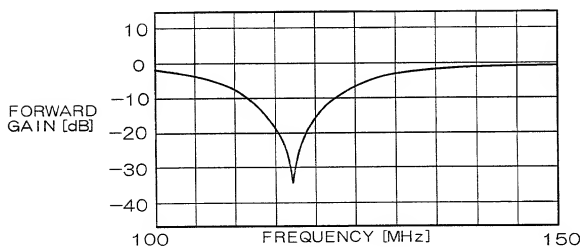
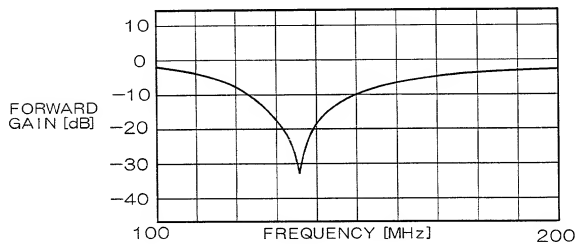
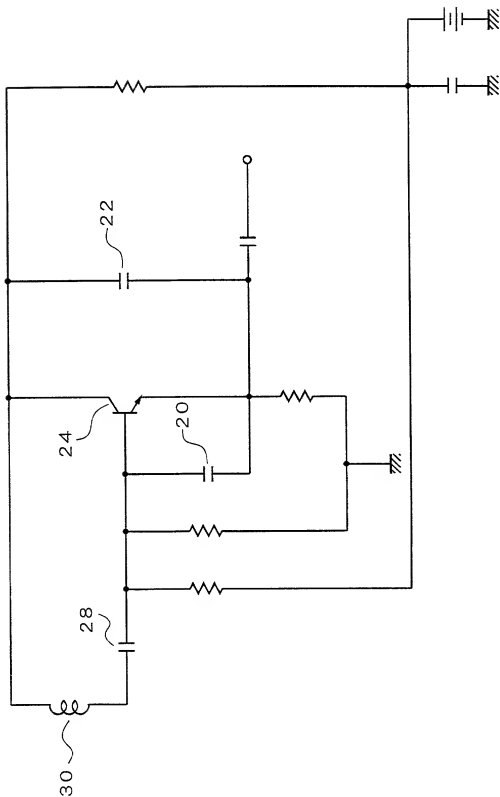


FIG. 9



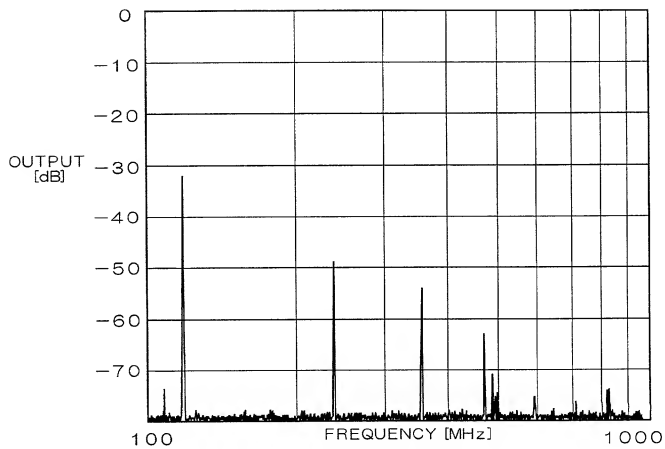
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FIG. 10



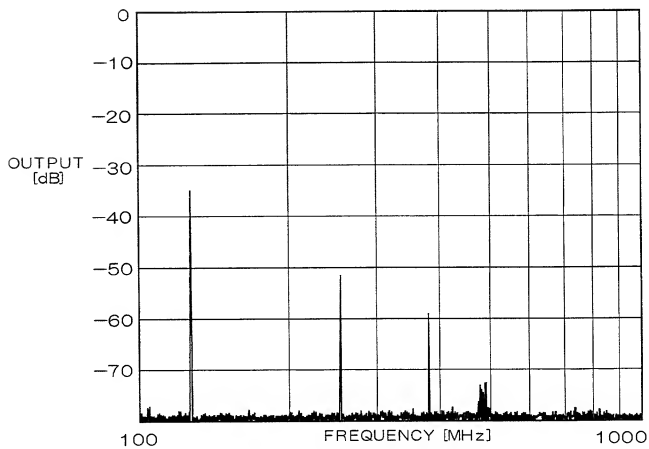
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FIG. 11



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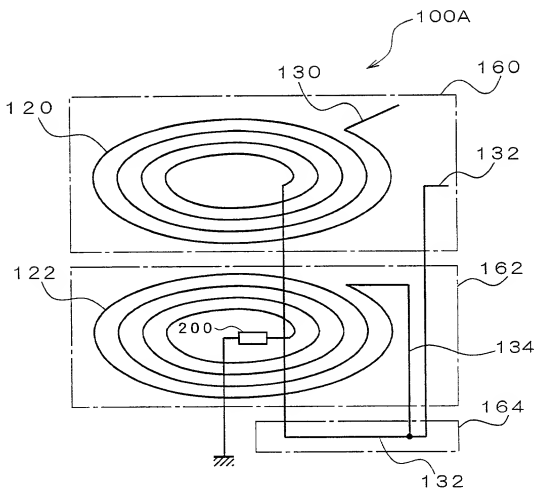
FIG. 12



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FIG. 13



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FIG. 14

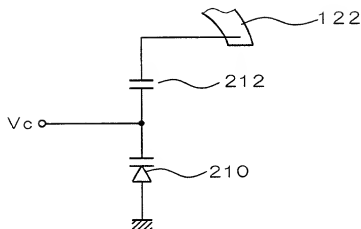


FIG. 15

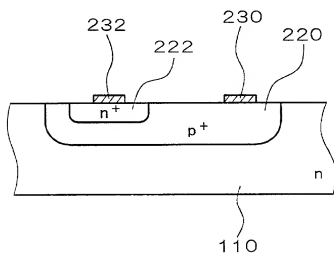
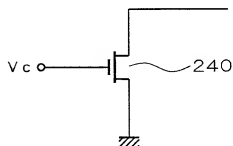
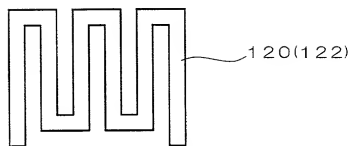


FIG. 16

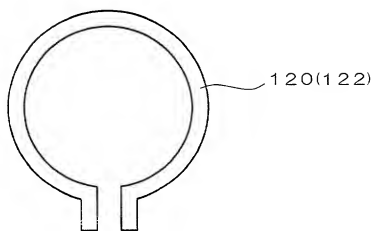




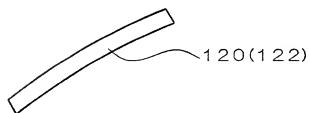
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*FIG. 17*



*FIG. 18*

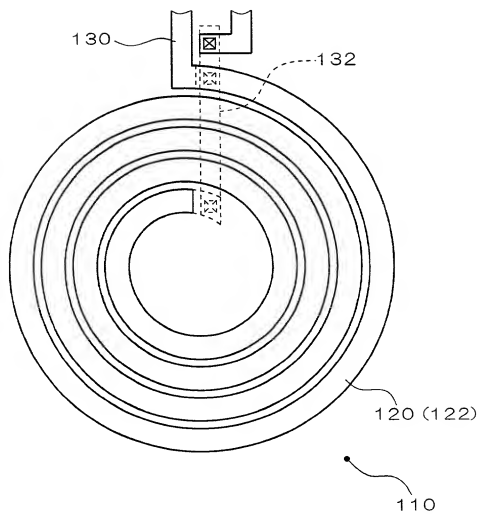


*FIG. 19*



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FIG. 20



I hereby claim the benefit under 35 U.S.C. Section 119(e) of any United States provisional application(s) listed below:

(Application Serial No.)

(Filing Date)

(Application Serial No.)

(Filing Date)

(Application Serial No.)

(Filing Date)

I hereby claim the benefit under 35 U. S. C. Section 120 of any United States application(s), or Section 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. Section 112, I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, C. F. R., Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application:

(Application Serial No.)

(Filing Date)

(Status)  
(patented, pending, abandoned)

(Application Serial No.)

(Filing Date)

(Status)  
(patented, pending, abandoned)

(Application Serial No.)

(Filing Date)

(Status)  
(patented, pending, abandoned)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Docket No.  
A-417

# Declaration and Power of Attorney For Patent Application

## English Language Declaration

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

### INDUCTOR ELEMENT

the specification of which

(check one)

☐ is attached hereto.

☒ was filed on 6 July 2000 as United States Application No. or PCT International Application Number PCT/JP00/04493 and was amended on \_\_\_\_\_

(if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d) or Section 365(b) of any foreign application(s) for patent or inventor's certificate, or Section 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)

Priority Not Claimed

11-192675

JAPAN

07 July 1999

☐

(Number)

(Country)

(Day/Month/Year Filed)

(Number)

(Country)

(Day/Month/Year Filed)

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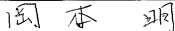
POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. *(list name and registration number)*

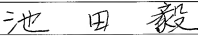
James H. Walters, Reg. No. 35,731

I authorize the attorney that I have appointed to accept instructions regarding this application and the resulting patent from Amagai Patent Firm.

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